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The impact of dynamic optical bandwidth provisioning on network resilience.

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A lot of work is going into understanding and defining the structure and functionalities of the future optical network. From the first optical networks that was characterized solely by a standardised way of using optical transmission systems in between the network nodes, the optical technology has matured and evolved in many ways, enabling more sophisticated functionalities and features.

A large amount of these proposals are aiming at offloading or complementing the higher layers of the network and actually introduce real network functionalities into the optical domain.

A significant part of this is a more dynamic (and more efficient?) exploitation of the bandwidth resources in the optical fiber, driven by an expected change in the behaviour of service and user demand, where general over provisioning is unrealistic (mainly due to the reduced ration between access bandwidth and bandwidth used in the core of the network).

1. Evolution in optical multiplexing techniques.

The first logical step has been using the WDM techniques to create a flexible wavelength network that provides a higher level of connectivity for the upper layers than given by the physical cables. However with 10Gbit/s becoming the most common and economical bitrate per wavelength the granularity is usually to low for most application and multiplexing methods for the time domain is heavily investigated to make the optical layer more efficient and capable in further offloading of the upper electronic layers.

Two concepts of time domain switching has been heavily investigated for adoption in the optical domain, optical packet switching and optical burst switching. Optical packet switching has in many cases been seen at the ultimate multiplexing solution for the optical layer as it is expected to be the most optimal way of carrying traffic based on the Internet protocols. But as for electronic packet switching, the optical counterpart has many “flavours” – perhaps even more than electronics - basically due to the lack of optical memory. Issues like fixed vs. variable packet size, label with routing tag vs. header with full destination address, integrated vs. separate control information with respect to payload are just some of the issues that makes optical packet switching far from mature enough for standardisation and operational deployment (e.g. should a standard be made, based the current available technology or based on expected innovation in the coming years).

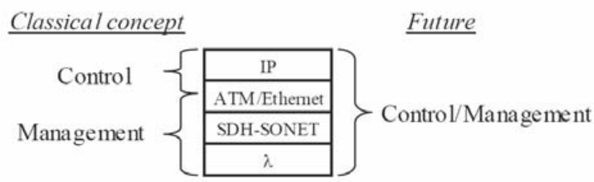
Optical burst switching is seen as an intermediate step for introducing time domain multiplexing in the optical layer. The concept is not new, but was already standardised for electronic networks (e.g. ATM, where it was an overlay to cell switching, implemented to simplify the control system).

Optical burst switching belongs somewhere in between optical packet switching and optical circuit switching. Its actual location is strongly dependent on the efficiency of the control system applied, i.e. whether a burst I similar to a long packet or a circuit with short holding time (fast circuit switching).

An alternative to wavelength based circuit switching is using OTDM in a more advanced way than used purely for transmission. Structuring the bits in octet or longer words (either physical or logical) can simplify the electrical interface and enable significantly higher bit rates in the core network.

2. Evolution of control and management systems

A key factor for the structure of the future optical network (in addition to development of new optical components and integration of these in advanced – low cost - optical devices) is the future structure of the control and management systems for the total network (not only the optical layers). In classical networks the physical infrastructure was administrated by a management systems while the logical upper layers where handled by some kind of control system (e.g. users driven signalling or routing concepts)



However having two separate systems, where the upper part is highly automated and the lower part mainly based on human operation, is both very costly from an operational point of view and potentially inefficient from a resource utilisation perspective. Due to that a lot of research and innovation is put into renewing the administration of the lower layers – unfortunately with a number of different approaches. The two main approaches are ASON (driven by the ITU) and GMPLS (driven by IETF).

The main conceptual difference between the two concept is while the GMPLS approach is aiming at a full integration of all network layers into a single system, the ASON approach is maintaining a separation between higher layers (typically packet or cell switched) and lower layers (typically circuit switched).

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But for both concepts the intension is to automate the administration as much as possible and minimize the need for human interaction in creating new connection, modifying existing connection or releasing connections.

General cost optimisation of the network administration and significant change in demand for bandwidth dynamics is behind these trends and evolution - an evolution with a lot of expectation but also some scepticism. While the advances are fairly obvious the risk and drawback are not so clear, but potentially were high.

If the traffic pattern in the core network remains fairly static and not as dynamic as some peer-to-peer application has indicated, then the resource utilisation might end up being less efficient than the classical approach as the algorithms for automated control usually are less complex and take into account only local performance metrics in order to limit the response time. The automated systems might be designed to be load dependent in such a way that in case the demand for re-optimisation is low then more parameters can be included – however the use of dynamic rule sets in a dynamic infrastructure can easily lead to an unstable network with low resilience.

3. Evolution of network resilience system

The requirement for a stable and reliable network has been a key parameter in network operation for many years and a clear differentiator for different operators. High level of reliability or resilience is usually obtained as a complicated combination of failure recovery systems in the different layers and domains of the network. It is a general rule that the larger the impact of a failure might be, the stronger and faster the resilience concept must be. It has been traditional thinking that cable failures are the most severe kind of errors as a fiber optical cable with tens or hundreds of fibers easily can impact hundred thousands of users. However protocol algorithms used in networks today are becoming so complex and inter-related, that formal proof or verification is impossible and the impact of faulty parameters settings can be far more severe than a cable failure as the whole network can be dragged into a deadlock situation that is hard to get out off.

For that reason it is important in any automation of the network to evaluate the impact on the network resilience.

However the network resilience concept is also going through the same kind of changes as other parts of the network. In classical networks a conservative approach with network protection is commonly used. This concept by definition takes away half of the available capacity and it is obvious that alternative solutions are attractive, if they can prove to be equally fast and reliable as the classic approach. The alternative approach to network protection is network restoration i.e. instead of creating a back-up resource at the same time as the primary resource, the system ensures (with some probability) that resources are available, but these resources will not be assigned prior to the failure. This concept is off course only usable if the resources can be assigned within reasonable time (usually in the millisecond range). With an automated control system that incorporate all layers of the network down to fiber and wavelength level it is hard to have an accurate picture of available resources in the network and as such it is hard to provide the very high level of resilience in any part of the network.

4. Conclusion

The optical network is continuously evolving, but while higher and higher bitrates was the focal point in the past, the focus is now more on the operation systems that to a higher extend is seeking integration into holistic administrative concept where application level action can impact the topology in the physical layer.

This integration in a fully automated system might even include the concept for ensuring network resiliency. It however needs to be verified whether such a system will in it self be a significant contributor to a less stable and reliable network.

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